Silvical Characteristics of White Ash

(*Fraxinus americana*)

by Jonathan W. Wright

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Preface

MUCH of the silvical information on our forest trees is widely scattered and sometimes difficult to find. To make this material more readily available, the Forest Service is assembling information on the silvical characteristics of all the important native forest tree species of the United States. It is expected that this information will be published as a comprehensive silvics manual.

This report presents the silvical characteristics of one species. It contains the essential information that will appear in the general manual but has been written with particular reference to the species in the Northeast. Similar reports on other species are being prepared by this Experiment Station, and by several of the other regional forest experiment stations.

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About the Author ...

JONATHAN W. WRIGHT *took his B.S. degree in forestry at the University of Idaho in 1938. He received M.F., M.A., and Ph.D. degrees at Harvard University, with genetics his major field. From 1942 to 1945 he was an instructor in forestry at Purdue University. He joined the Northeastern Forest Experiment Station the following year as geneticist, headquartered at the Morris Arboretum. A recognized authority on forest genetics, Dr. Wright has published many papers both in this country and abroad. He left the Experiment Station in 1957 to become Associate Professor of Forestry at Michigan State University, East Lansing, Mich.*

The White Ash

WHITE ASH *(Fraxinus americana* L.) derives its common name from the white under-surface of the leaf; the white effect is created by microscopic papillae with a high light-reflecting capacity. The specific name *americana* was given to the species because of its range in America *(38, 42).* [1]

This species is the largest, commonest, and most useful--but not the most widespread--of the American ashes. Its natural range extends from Nova Scotia westward to Winona County, Minnesota, and southward to eastern Texas and northern Florida (fig. 1). In eastern Texas it intergrades with the closely related Texas ash *(F. texensis* (A. Gray) Sarg. = *F. americana* ssp. *texensis* (A. Gray) Miller), but elsewhere in its range it is distinct from the other ash species *(37, 38, 43, 50).*

White ash has been planted abroad frequently as an arboretum tree but rarely as a forest tree. It has been successful when grown under conditions similar to those encountered in its native range. In England and France its performance compares favorably with that of the native European ash *(F. excelsior L.).*

In native stands, white ash is frequently mistaken for green ash (*F. pennsylvanica* Marsh.), from which it differs in having the white under-leaf surface, less sharp leaf serrations, and a cigar-shaped seed with a terminal wing attachment. It is also confused sometimes with the pumpkin ash (*F. tomentosa* Michx.), from which it can be distinguished by the above three characteristics and by its generally smaller leaves, flowers, and fruit. The differences among the species are quantitative but nevertheless distinct.

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[1] Italic numbers in parentheses refer to Bibliography, page 15.

Habitat Conditions

CLIMATE

The variation in the principal climatic factors is as follows in the natural distribution area of white ash: total annual precipitation--30 to 60 inches; warm season precipitation--20 to 44 inches; average annual snowfall--0 to 80 inches; average January temperature--15° to 55° F.; and average length of frost-free period--120 to 280 days *(59)*.

The evidence as to which of these factors are most responsible for limiting the natural range is fragmentary. Irrigated park trees in semi-arid Spokane, Washington, are vigorous, indicating that relative humidity is unimportant if there is adequate soil moisture. Geographic-origin tests in Massachusetts[2] and Pennsylvania *(64)* showed that minimum water temperature, day length, and length of frost-free period were important in governing the performance of ecotypes within the species. Poor growth of trees kept continously in a warm greenhouse shows a need for some low temperature during the winter. But we still do not know whether the species would thrive if planted under conditions outside the range of extremes given above.

SOILS

White ash is most commonly found on gray-brown and brown podzolic soils. It is a demanding species as regards soil fertility and soil moisture. Its requirements, however, may be supplied by soils from a variety of parent materials such as limestone, basalt, shale, alluvium, and fine glacial till. Its pH tolerance ranges at least from 5.0 to 7.5.

Cummings' *(21)* and Wallihan's *(63)* studies of local distribution indicate that white ash grows most commonly on fertile soils with a high nitrogen content and a moderate to high calcium content. Planting experiments support the evidence from natural stands that the high fertility and soil moisture are actually needed. For example, good growth equal to that in natural stands was obtained on a "first-class agricultural soil" in Tioga County, Pennsylvania *(19)*, on New York old fields high in nitrogen *(63)*, and on Maryland Piedmont soils that supported vigorous growth of other moisture-loving hardwoods.[2]

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[2] In preparing this paper, the author has drawn freely upon unpublished data of the Harvard Forest, Petersham, Mass., and the U. S. Forest Service Northeast. Forest Expt. Sta., Upper Darby, Pa.

But the majority of the white ash test plantings have been made on poor soils and have grown at only a fraction of the rate found in natural stands. The 46-year-old planting described by Den Uyl *(22)* is typical of the results to be expected on infertile sites. This planting was cultivated through its first 4 years and more than half the trees were still alive after 46 years. But at that time the largest of the planted trees was only 8 inches in diameter breast high and the majority ranged from 3 to 6 inches.

Soil moisture is also an important factor limiting the local distribution of white ash; the species reaches its best development on moderately well-drained soils. Stout's soil-pit studies at the Harvard Forest showed white ash to be limited mostly to those areas underlain by a compacted glacial till at a depth of 20 inches or less, which supports a perched water table during rainy periods *(57)*. In lower Michigan, white ash is an appreciable component of the stands on podzolic soils underlain by heavy clay and high water tables, but is nearly absent on soils underlain by light-textured, well-drained, glacial drift *(24)*. We do not yet know whether too much moisture

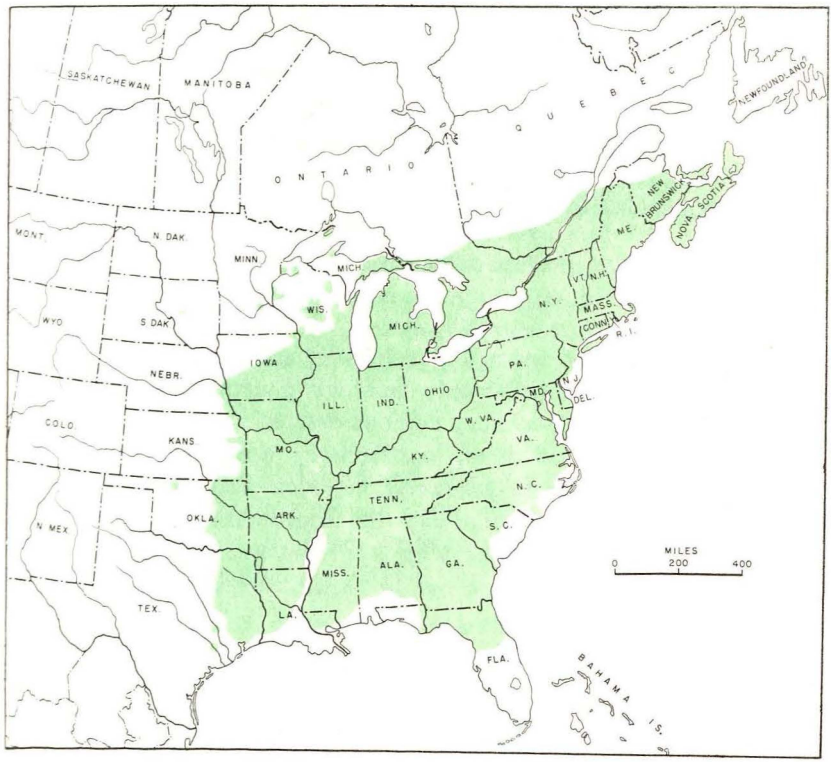

Figure 1.--*The natural range of white ash.*

is actually detrimental. White ash is rarely found in swamps (which are usually acid and subject to late spring frosts as well as being wet), but is comparatively tolerant of temporary flooding *(29, 34)*.

White ash is one of the best soil-improving species. Its leaves are high in calcium (2.19 percent in one New York test) and return available calcium to the soil promptly *(14)*. They are also very palatable to earthworms *(32)*. This can easily be substantiated by examining the litter under ash trees a few months after leaf fall: usually no ash leaves will be found, although leaves of other species in the vicinity such as oaks, maples, beech, and pine will still be abundant.

PHYSIOGRAPHIC

White ash ranges from near sea level in the Coastal Plain to about 3,500 feet in the Cumberland Mountains *(6)*, and up to about 2,000 feet in the Adirondack Mountains of New York *(9)*. In the hilly or mountainous sections of the Northeast it is found on the mesophytic lower or middle slopes, usually stopping far short of both the dry oak-pine ridge tops and the cold spruce-fir forests of the mountain tops. In the Coastal Plain it is usually limited to the slightly elevated ridges in the bottoms of major streams. In the Central States it is most common on slopes along major streams, although also found in a great variety of upland situations. Rarely is white ash a common tree in the flat bottoms of major streams or in depressions where there is poor air drainage.

BIOTIC

Associated plants

White ash is a minor but relatively constant component of forests in the birch-beech-maple-hemlock, chestnut-chestnut oak-yellow-poplar, and oak-hickory regions defined by Schantz and Zon *(52)*, or in the oak-chestnut, oak-hickory western mesophytic, mixed mesophytic, maple-basswood, hemlock-white pine-northern hardwoods regions of Braun *(8)*. On appropriate sites in these regions it usually comprises 3 or 4 percent (rarely more than 10 percent) of the stand volume but is rarely absent over extensive areas.

White ash is listed as a component in 26 of the cover types recognized by the Society of American Foresters for eastern North America *(18)*. It is a major species in the white pine-northern red oak-white ash and northern red oak-basswood-white ash cover types, and is common in several other types in association with

such dominants as eastern white pine *(Pinus strobus* L.), northern red oak *(Quercus rubra* L.), white oak *(Q. alba* L.), sugar maple *(Acer saccharum* Marsh.), red maple *(A. rubrum* L.), yellow birch *(Betula alleghaniensis* Britton), American beech *(Fagus grandifolia* Ehrh.), black cherry *(Prunus serotina* Ehrh.), American basswood *(Tilia americana* L.), eastern hemlock *(Tsuga canadensis* (L.) Carr.), American elm *(Ulmus americana* L.), and yellow-poplar *(Liriodendron tulipifera* L.).

Among the understory shrubs and small trees commonly found where ash grow are downy serviceberry *(Amelanchier arborea* (Michx. F.) Fern.), pawpaw *(Asimina triloba* (L.) Dunal), American hornbeam *(Carpinus caroliniana* Walt.), flowering dogwood *(Cornus florida* L.), witch-hazel *(Hamamelis virginiana* L.), eastern hop-hornbeam *(Ostrya virginiana* (Mill.) K. Koch), and the dockmackie *(Viburnum acerifolium* L.). The commonest associated herbs are maidenhair-fern *(Adiantum pedatum* L.), rock polypody *(Polypodium virginianum* L.), bellwort *(Uvularia grandiflora* Sm.), false spike-nard *(Smilacina racemosa* (L.) Desf., wild ginger *(Asarum canadense* L.), wild jalap *(Podophyllum peltatum* L.), rue-anemone *(Anemonella thalictroides* (L.) Spach.), papoose-root *(Caulophyllum thalictroides* (L.) Michx.), and the blue-stem goldenrod *(Solidago caesia* L.).

Animals & Birds

The seeds of the white ash are eaten by the wood duck, bob-white, purple finch, pine grosbeak, and fox squirrel. Rarely are the amounts eaten sufficient to affect reproduction *(27, 41)*. Animal feeding on the foliage is important, however, and this species is one of the first to disappear under heavy browsing by cattle or deer. Cottontail rabbits, beavers, and porcupines make occasional use of the bark of young trees for food *(41, 62)*.

Insects & Diseases

White ash has 12 insect and disease pests worthy of mention. Some cause occasional severe local damage. However, none has ever become serious over large areas nor has threatened the species with extinction *(17, 20)*.[3]

Of the insect pests, the oystershell scale *(Lepidosaphes ulmi* (L.)) is the most serious; severe infestations cause yellowing and, if prolonged, may kill some trees. The brown-headed ash sawfly *(Tomostethus multicinctus* Roh.) and the black-headed

[3]Alma M. Waterman, personal communication.

ash sawfly *(Tethida cordigera* (Beauv.)), are defoliators that attack planted shade trees mainly. The forest tent caterpillar *(Malacosoma disstria* Hbn.) and the green fruitworm *(Graptolitha antennata* (Wikr.)) are other defoliators that work mostly in forest stands and occasionally cause complete defoliation over small areas. The ash and privet borer *(Tylonotus bimaculatus* Hald.) is a secondary factor in the death of large shade trees previously injured by drought. An unidentified seed weevil sometimes infests nearly all seeds of a few trees in a stand; the seeds of neighboring trees may be unharmed.

The fungus *Mycosphaerella fraxinicola* (Schw.) House causes a leaf spot and premature defoliation of young trees. Anthracnose *(Gloeosporium aridum* Ell. and Holw.) also causes premature defoliation. It is most serious after exceptionally wet springs. A rust *(Puccinia peridermiospora* (Ell. and Tr.) Arth.), with grasses as alternate hosts, results in distortion of petioles and small twigs. Cankers caused by *Nectria galligena* Bres. result in breakage of branches but rarely are found on the main stem. The white mottled heartwood rot caused by *Fomes fraxinophilus* (Pk.) Sacc. gains entrance through wounds or broken branches. It is more prevalent in the Midwest than in the East.

Life History

FLOWERING AND FRUITING

White ash is dioecious; that is, some trees are male, some female. The ratio of male to female trees is probably 1:1. However in any given year more male than female trees bloom. In the vicinity of Philadelphia, Pa., some male trees flower heavily every year, but the most prolific female trees flower only 2 or 3 years out of 5. Open-grown vigorous trees may start to bloom when only 3 or 4 inches in diameter. However, trees are usually 8 to 10 inches in diameter before they produce flowers abundantly. As far as is known, the older and larger the tree, the more abundantly it blooms. The flowers are usually distributed regularly over the entire outer portion of the live crown *(67)*.

Full bloom occurs before the leaf buds start to enlarge--in April in Florida *(15)* and in middle or late May in Pennsylvania

(67). On male trees 2 to 3 weeks elapse from the time there is a noticeable enlargement of the winter buds until pollen-shedding is complete. Pollen-shedding of a single tree usually occupies a period of 3 or 4 days; that of a stand lasts 5 to 7 days. Most of the pollen, which is wind-carried, travels only a few hundred feet from the point of dispersion *(65)*.

Flowering is much more hurried on female than on male trees. The buds are completely open a few days after they start to swell. The exposed flowers are ready for pollination immediately and continue in a receptive state for about a week. The period of receptivity is past as soon as the tips (stigmas) of the flowers discolor. About half the flowering trees bear abundant crops of seed. The rest bear almost none. In 1947 the Philadelphia seed crop failure was known to be due to a late spring frost. In other years it occurred for no apparent reason.

White ash must be pollinated to produce seed, and it does not cross readily with other ash species occupying the same range *(66)*. Therefore, all ripe seeds are usually the result of pollination by other nearby trees of the same species *(65)*. The seed is dispersed up to 450 feet (19). In view of the low percentage of trees that seed abundantly and the limited distances to which pollen and seed are dispersed, full stocking of any considerable cut-over area can probably be achieved only by retaining four to six trees per acre.

VEGETATIVE PROPAGATION

Stumps of freshly cut seedling and sapling white ash sprout readily. The sprout clumps usually contain only one or two stems. This species is about as easy to propagate by conventional methods of budding or grafting as the common fruit trees *(47)*. Even open-field and bench grafting of unpotted stock gives high percentages of success. As yet we know of no reliable method for rooting cuttings *(58)*.

SEED GERMINATION and SEEDLING DEVELOPMENT

Freshly collected white ash seed is dormant and requires 2 to 3 months' moist stratification at refrigerator temperatures to germinate *(54, 60)*. This dormancy is believed to be due to the fact that the endosperm contains an inhibitor that diffuses out of the seed during stratification. There is considerable tree-to-tree variation in the ease with which dormancy can be overcome.

To approach 100-percent germination it is necessary to sterilize the seeds, stratify them properly, sow them 1/4 to 1/2

inch deep in mineral soil, and keep the seedbed surface constantly moist until germination is complete. This is easily done in the nursery. In the field the requisite conditions are rarely met with and germination is rather low--probably less than 1 percent in most cases. In the forest a large proportion of the seeds rot the first winter.

Optimum growing conditions for seedling white ash have not been determined experimentally. Field and nursery observations indicate that optimum conditions would include: full sunlight, high soil fertility (especially with regard to nitrogen), high soil moisture until early autumn, freedom from competing vegetation, and 60 to 70 square inches growing space per seedling during the first growing season (more in later years). The maximum growth attainable is not known but is probably greater than the 1 foot in 1 year or 2-1/2 feet in 2 years obtained in experimental nurseries to date.

Optimum seedling growing conditions are rarely found in nature. In the forest, low light intensity, root competition, frost damage, and deer browsing are among the adverse factors that often limit seedling height growth to as little as 1 foot in the first decade. Grass competition is a limiting factor in old fields of the Northeast, where 12 to 15 years are sometimes required for a seedling to reach breast height.

White ash seedlings can stand more mishandling in the nursery than the seedlings of almost any other commonly planted tree. They can be top-pruned, root-pruned to 1 or 2 inches, split longitudinally, left heeled-in in crowded bundles for a few years, or left with their roots exposed to the sun for a minute or two and still recover promptly if transplanted to a good soil and cultivated. They show this same ability to recover quickly after release from deer browsing or shading.

Photoperiodic response of the seedlings appears to vary geographically. Kramer *(35)*, probably working with a North Carolina ecotype, found no growth response in seedlings grown under a 14-1/2-hour daylength. On the other hand, a photoperiodic response was evident in a Massachusetts test, in which northern ecotype seedlings stopped height growth and dropped their leaves well before the first frost, while southern ecotype seedlings continued height growth until late autumn *(64)*.

There is strong apical dominance in young ash trees that causes them to be comparatively branchfree and to grow vertically.

Figure 2.--*Young white ash trees tend to grow straight up and develop relatively branch-free stems.*

Thrifty open-grown seedlings 5 or 6 feet tall often have only two or three pairs of lateral branches and may have none. If the terminal bud is removed, this apical dominance is lost and new branches develop quickly from the uppermost pair of live lateral buds. Almost always one of these grows a little faster than the other, assumes dominance, and causes the second one to become just another branch. This apical dominance is also lost if a young tree is planted crooked or bent over. When this happens a new sprout grows vertically from the base and suppresses the former main stem. For this reason cases of severe lean and crooked bases are rare in the species.

SAPLING STAGE TO MATURITY

Depending upon the amount of root competition, a tree in full sunlight may take 3 to 15 years to reach breast height. Once

it has reached this height, its root system is normally well established and it is able to grow rapidly even though surrounded by weeds. The post-juvenile growth rates of dominant and co-cominant trees in unthinned even-aged stands in central Mass-achusetts are shown in the following tabulation *(30, 46)*:

Age at breast height (years)	*Diameter breast high (inches)*	*Height (feet)*
20	4	38
30	7	57
40	10	68
50	12	76
60	14	82
70	17	90

There are no yield tables for white ash in pure stands, nor are there data on the maximum growth rates attainable by individual trees over long periods of time. One specimen near Philadelphia grew 55 feet tall and 15.2 inches diameter breast high in the 22 years since it was outplanted as a small seedling.

White ash trees 70 to 80 feet tall are common in mature forests, and trees 120 feet tall and 6 feet in diameter breast high have been found in the Ohio River Bottomlands. Braun *(7)* found a fallen tree in the Cumberland Mountains that was 40 inches in diameter breast high and 100 feet to the first large branch. In the AMERICAN FORESTS list of outstanding specimens the size records go to two trees in Glenn Mills, Pa. They are respectively 80 and 98 feet tall, 7.1 and 6.7 feet in diameter breast high, and 82 and 90 feet in crown spread *(1, 2)*.

Open-grown trees commonly remain single-stemmed and fine-branched until they are 30 or 40 feet tall, although old specimens can become as broad-crowned as an elm. With even slight crowding the single-stemmed characteristic can easily be maintained throughout a rotation. In this respect white ash is easier to manage than any other eastern hardwood except yellow-poplar.

Uninjured terminal buds suppress the growth of all lateral buds on the current year's growth, and suppress the growth of other laterals to such an extent that each internode has only one pair of branches that persist more than a few years. Even the strongest lateral branches grow only half as fast as the terminal

except on old open-grown trees. There is little or no epicormic branching on the boles of released trees *(55)*. The branches of dominant trees emerge from the bole at about at 35° angle from the vertical whereas the branches of intermediate trees emerge at an angle of about 55°.

Shade-killed branches drop quickly--small ones within a year or two and larger ones within 4 or 5 years. The mechanism by which this self-pruning is achieved involves, among other things, rapid invasion and weakening by saprophytic fungi, whipping by wind, sleet, snow, and the branch's own weight. There are no data on the rate of healing of scars left by dead branches, but live-pruned branch scars heal more quickly in white ash than in other northern hardwood species *(55)*. In thinned but unpruned red oak-white ash stands in central Massachusetts the white ash clear length varied from 30 percent of the total height for 50-foot trees to 42 percent for 90-foot trees *(30)*.

In New York and Connecticut the vegetative buds start to enlarge about the first of May. Springwood formation is complete throughout the bole before summerwood formation starts. Diameter growth continues until about August 1 in the bole and until late September in the roots. However, height growth ordinarily is 90 percent completed in the first 30 days, and 100 percent completed in 60 days *(33, 39)*.

GROWTH CONDITIONS and WOOD CHARACTERISTICS

There is an obvious relationship between growth conditions and log quality: open-grown trees have more and larger branches, hence produce logs of lower grade because they have more and larger knots than do forest-grown trees. There is only a slight correlation between growth rate and wood quality. Current ax-handle specifications exclude logs having less than 5 or more than 17 rings per inch, but make no distinction between logs varying within those limits *(48, 61)*.

TOLERANCE and PLACE IN SUCCESSION

In its youth, white ash is a shade-enduring tree. Seedlings can survive for years under a canopy that allows less than 3 percent of full sunlight to reach the ground, but under such

conditions they grow little *(19)*. Seedlings that receive more than 3 percent of full sunlight can make appreciable growth *(28)*. With increasing age white ash becomes more intolerant, and in most lists it is ranked as intermediate-intolerant or intolerant. The decrease in tolerance with increasing age is reflected in the fact that white ash is present in relatively larger proportions in the understory than in the overstory of northern hardwood stands. When judged by the rapidity of death of shaded branches it is considered very intolerant.

White ash can be maintained more easily in a dense stand than can some of its associates such as northern red oak. For example, Cope *(19)* recommended a stocking at age 60 of 120 13-inch white ash trees per acre or 45 20-inch northern red oak trees per acre. However, dominant or co-dominant white ash responds readily to thinning and within a few years will increase its crown area sufficiently to take full advantage of any reasonable thinning.

In a study in central Massachusetts, thinnings that resulted in an approximate doubling of crown diameter in pole-sized stands also resulted in a doubling of the basal-area growth on individual trees; over a large range of diameters there was a direct linear relation between crown diameter and basal area growth over a 10-year period *(31)*.

White ash is a pioneer species that seeds in on the more fertile abandoned fields in several parts of the country, for example in central and western Massachusetts, northern New Jersey, New York, southern Michigan, and Ohio. However, pioneer ash often does not develop into good timber trees unless other hardwoods or pines also come in and develop to such a size as to provide protection. In the Southeastern States much of the land abandoned after agricultural exploitation is incapable of supporting demanding species. On such sites white ash comes in only after some site protection and improvement has been accomplished by volunteer or planted pines *(3, 4)*.

Despite its relatively low tolerance, white ash is characteristic of intermediate as well as early stages of natural plant succession. Throughout its range it is a minor but constant component of both the understory and overstory of mature forests on suitable soils. It owes its position in the final overstory to its ability to persist for a few years in moderately dense shade and to take quick advantage of any openings in the canopy created by death of an occasional old tree.

Genetic Variation

The white ash species contains several phenotypic variants of leaf form that seem to be under genetic control even though they are randomly distributed throughout the population. Chief among these are a 9-leaflet form, a narrow-leaflet form, a blunt-leaflet form, an ascidiate leaflet form, a partially pubescent form, a purple-keyed form, and a crinkle-leaf form *(50, 64)*.

There are also several characteristics known to be under genetic control and to have special geographic distributions *(64)*; these distinguish the three presently recognized geographic ecotypes:

The northern ecotype (Canada, northern New England, New York, and the Lake States) is fairly uniform over its entire range. It is slow-growing, rough-leaved, susceptible to aphid attack, glabrous, subject to early leaf fall, subject to leaf damage by early fall frosts, winter-hardy, and diploid (2n = 46 chromosomes). It has green petioles and purple fall leaf color, and the lower surfaces of its leaves are greener than in southern trees.

The intermediate ecotype (western Connecticut, southern Pennsylvania, northern West Virginia, and parts of Ohio) is closer to the northern than to the southern population in most respects. However, it resembles the latter in containing a polyploid series.

The southern ecotype (Maryland, southern Indiana, and southward) is variable and probably should be subdivided. As compared with the northern ecotype, it is faster growing, smoother leaved, less susceptible to aphid attack, pubescent or glabrous, subject to later leaf fall, less subject to leaf damage by fall frosts, less winter-hardy, and is variable in chromosome number (2n = 46, 92, or 138). The lower surfaces of the leaves are white. The petioles are red and the leaves turn yellow in the autumn.

When grown under uniform conditions in a single nursery these geographic ecotypes are as easily distinguishable as are many species. However, they have not received and do not deserve Latin names because they are not morphologically distinguishable in their natural habitats.

White ash and Texas white ash intergrade in Texas, and there is considerable merit in considering them as sub-species, as Miss Miller did *(43)*. The pumpkin ash behaves in many respects as if it

were a true-breeding hexaploid derivative of a cross between tetraploid white ash and diploid green ash. However, attempts to cross the two species artificially have failed *(66)*, and it is likely that hybridization between white ash and other species is extremely rare in nature. The ecotypic differentiation mentioned above seems to have taken place within the single species, not as a result of introgression.

Special Features

The most remarkable characteristic of white ash is the toughness of its wood. It is the preferred species for making baseball bats, hammer handles, ax handles, skis, and other wooden objects in which the ability to resist impact is important.

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